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NATIONAL EUTROPHICATION SURVEY

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

WINONA LAKE

KOSCIUSKO COUNTY

INDIANA

EPA REGION V

WORKING PAPER No. 348

WITH THE COOPERATION OF THE

INDIANA STATE BOARD OF HEALTH

AND THE

INDIANA NATIONAL GUARD

APRIL, 1976

CONTENTS

	Page
Foreword	ii
List of Indiana Study Lakes	iv
Lake and Drainage Area Map	v
Sections	
I. Conclusions	1
II. Lake and Drainage Basin Characteristics	4
III. Lake Water Quality Summary	5
IV. Nutrient Loadings	9
V. Literature Reviewed	13
VI. Appendices	14

FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning {§303(c)}, water quality criteria/standards review {§303(c)}, clean lakes {§314(a,b)}, and water quality monitoring {§106 and §305(b)} activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Indiana State Board of Health for professional involvement, to the Indiana National Guard for conducting the tributary sampling phase of the Survey, and to those Indiana wastewater treatment plant operators who provided effluent samples and flow data.

The staff of the Division of Water Pollution Control, Indiana State Board of Health, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

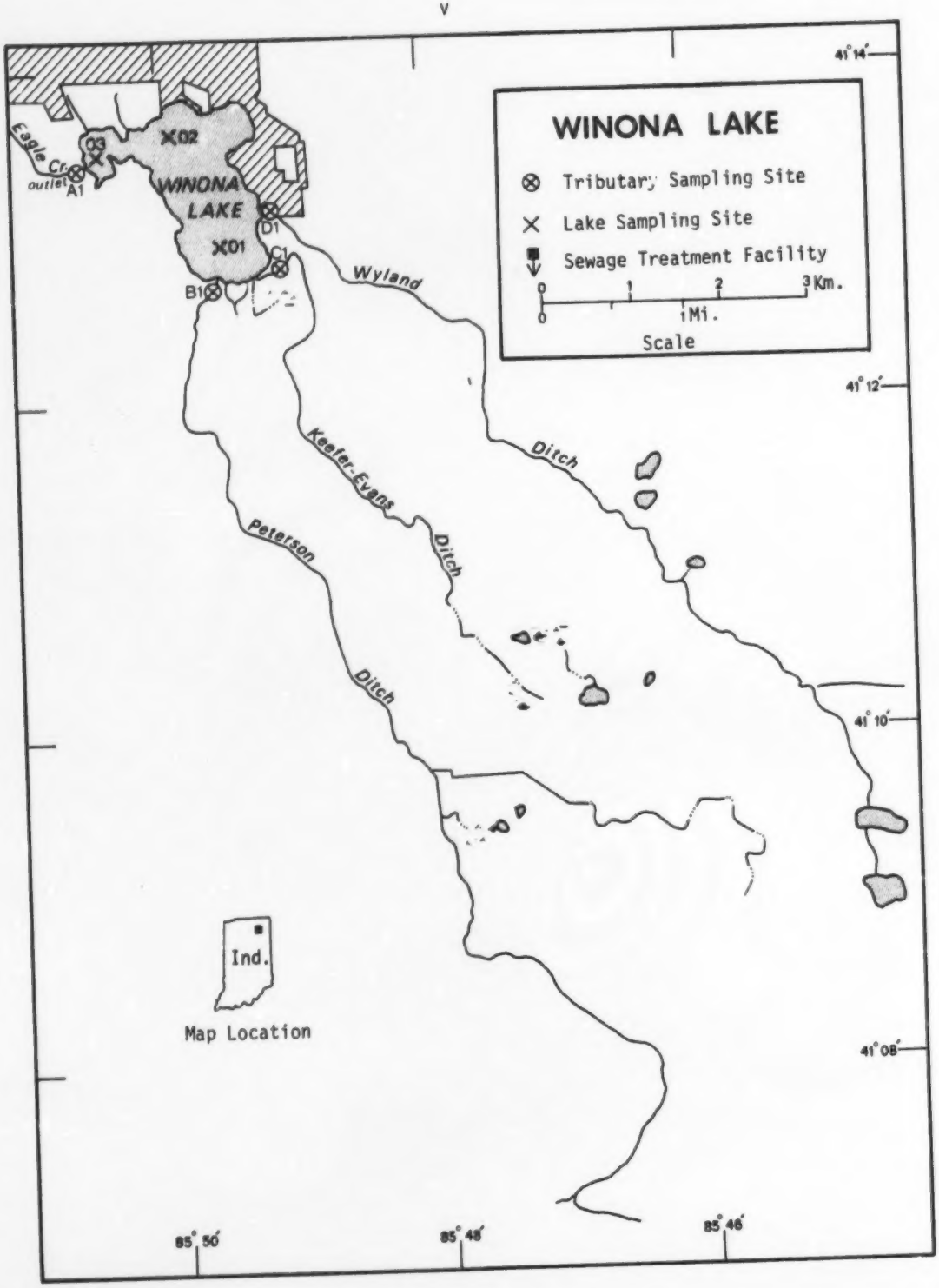
Major General Alfred F. Ahner, Adjutant General of Indiana, and Project Officers Lt. Colonel Charles B. Roberts (Retired) and Colonel Robert L. Sharp, who directed the volunteer efforts of the Indiana National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF INDIANA

LAKE NAME	COUNTY
Bass	Starke
Cataract	Owen, Putnam
Crooked	Steuben
Dallas	LaGrange
Geist	Hamilton, Marion
Hamilton	Steuben
Hovey	Posey
James	Kosciusko
James	Steuben
Long	Steuben
Marsh	Steuben
Mississinewa	Grant, Miami, Wabash
Maxinkuckee	Marshall
Monroe	Brown, Monroe
Morse	Hamilton
Olin	LaGrange
Oliver	LaGrange
Pigeon	Steuben
Sylvan	Noble
Tippecanoe	Kosciusko
Versailles	Ripley
Wawassee	Kosciusko
Webster	Kosciusko
Westler	LaGrange
Whitewater	Union
Winona	Kosciusko
Witmer	LaGrange


WINONA LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
0 1 2 3 Km.
0 1 Mi.
Scale
41° 14'
41° 12'
41° 10'
41° 08'
85° 50'
85° 48'
85° 46'
Eagle Cr.
outlet
A1
X3
X02
WINONA LAKE
X01
D1
C1
B1
Wyland
Ditch
Keefer-Evans
Ditch
Peterson
Ditch
Ind.
Map Location

WINONA LAKE

STORET NO. 1840

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Winona Lake is eutrophic. Of the 27 Indiana lakes sampled in 1973, it ranked sixteenth in overall trophic quality when compared using a combination of six parameters*. Twelve of the lakes had less and two had the same median total phosphorus, 12 had less and one had the same median dissolved phosphorus, 19 had less median inorganic nitrogen, 11 had less mean chlorophyll a, and 16 had greater mean Secchi disc transparency. Depletion of dissolved oxygen with depth occurred at station 1 in October and at station 2 in August and October.

Survey limnologists observed emergent macrophytes along the shoreline near stations 2 and 3, and nuisance algal blooms have been reported to occur (Ketelle and Uttormark, 1971).

B. Rate-Limiting Nutrient:

The algal assay results indicate that Winona Lake was limited by phosphorus at the time the sample was taken (05/04/73). The lake data indicate phosphorus limitation in August as well but nitrogen limitation in October.

C. Nutrient Controllability:

1. Point sources--No known municipal or industrial waste-

* See Appendix A.

water treatment plants impacted Winona Lake during the sampling year. The Town of Winona Lake formerly discharged treated wastes to the lake; but as of February, 1972, the wastes were diverted to the Warsaw treatment plant which discharges downstream from the lake outlet (Winters, 1975).

At least four storm sewers discharge urban runoff to the lake; infrequent and unquantified spills of dairy wastes to one of the sewers could contribute nutrients to the lake (BonHomme, 1975). Another storm sewer of possible nutrient significance drains the Kosciusko County fairgrounds; nutrients in livestock wastes could reach the lake through the sewer, particularly if rainfall occurs when the County Fair is in progress (BonHomme, op. cit.).

The present phosphorus loading of 0.80 $g/m^2/yr$ is about one-third greater than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 12). Since the wastes of the Town of Winona Lake have been diverted, and assuming the storm sewer phosphorus loads prove not to be significant, the loading probably has been reduced about as much as is possible unless other sources prove to be controllable (see below). The lake should show gradual improvement in trophic condition once a new phosphorus equilibrium is established, but this may take several years because Winona Lake has a mean

hydraulic retention time in excess of 300 days.

2. Non-point sources--The phosphorus contribution of non-point sources accounted for 99.2% of the load to Winona Lake. Peterson Ditch contributed 36.3%, Wyland Ditch contributed 46.8%, and the Keefer-Evans Ditch contributed 10.0%. All three tributaries flow through some populated areas and probably are impacted by septic tanks to some degree (BonHomme, op. cit.). Further study is needed to determine the significance and controllability of these nutrient sources.

The phosphorus export rates of the three tributaries (page 11) were somewhat higher than the rates of tributaries sampled elsewhere is Kosciusko County; e.g., Turkey Creek (11 kg/km^2/yr) and Dillon Creek (12 kg/km^2/yr), tributaries of Lake Wawasee*; and the Tippecanoe River (11 kg/km^2/yr) and Grassy Creek (12 kg/km^2/yr), tributaries of Lake Tippecanoe**. The higher rates of the Winona Lake tributaries may be due to the septic tank impact noted above.

* Working Paper No. 344.
** Working Paper No. 342.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 2.27 kilometers^2.
2. Mean depth: 9.1 meters.
3. Maximum depth: 24.4 meters.
4. Volume: 20.657 x 10^6 m^3.
5. Mean hydraulic retention time: 319 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Peterson Ditch	30.0	0.28
Keefer-Evans Ditch	11.1	0.10
Wyland Ditch	36.0	0.34
Minor tributaries & immediate drainage -	3.7	0.03
Totals	80.8	0.75

2. Outlet -

Eagle Creek	83.1**	0.75**

C. Precipitation***:

1. Year of sampling: 79.7 centimeters.
2. Mean annual: 88.5 centimeters.

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† Table of metric conversions--Appendix B.
†† Winters, 1975.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake; outflow adjusted to equal sum of inflows.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Winona Lake was sampled three times during the open-water season of 1973 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at three stations on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 20.7 meters at station 1, 17.1 meters at station 2, and 3.7 meters at station 3.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR WINONA LAKE
STORET CODE 1840

	1ST SAMPLING (5/ 4/73) 3 SITES			2ND SAMPLING (8/ 4/73) 3 SITES			3RD SAMPLING (10/13/73) 3 SITES		
PARAMETER	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN
TEMP (C)	9.1 - 13.4	12.0	12.6	14.0 - 23.7	22.2	23.0	10.3 - 20.0	16.9	19.7
DISS OXY (MG/L)	6.4 - 9.8	8.9	9.0	0.0 - 8.5	6.0	6.5	0.0 - 8.4	3.6	2.0
CNDCTVY (MCROMO)	470. - 540.	507.	500.	411. - 462.	452.	461.	377. - 415.	400.	408.
PH (STAND UNITS)	8.2 - 8.4	8.3	8.3	7.5 - 8.6	8.3	8.4	7.4 - 8.5	8.0	8.2
TOT ALK (MG/L)	166. - 203.	197.	203.	176. - 212.	185.	183.	160. - 225.	181.	174.
TOT P (MG/L)	0.027 - 0.088	0.041	0.037	0.020 - 0.033	0.025	0.022	0.026 - 0.438	0.113	0.041
ORTHO P (MG/L)	0.004 - 0.056	0.016	0.011	0.003 - 0.011	0.005	0.005	0.007 - 0.376	0.083	0.018
NO2+NO3 (MG/L)	1.200 - 1.570	1.395	1.390	0.230 - 1.230	0.467	0.445	0.030 - 0.380	0.089	0.045
AMMONIA (MG/L)	0.070 - 0.320	0.130	0.110	0.050 - 0.190	0.091	0.065	0.040 - 2.420	0.551	0.100
KJEL N (MG/L)	0.600 - 0.900	0.765	0.800	0.700 - 1.200	0.910	0.900	0.600 - 3.800	1.612	1.250
INORG N (MG/L)	1.400 - 1.670	1.525	1.530	0.300 - 1.410	0.558	0.500	0.070 - 2.480	0.640	0.140
TOTAL N (MG/L)	2.010 - 2.290	2.159	2.160	1.050 - 2.030	1.377	1.310	0.660 - 3.860	1.702	1.290
CHLRPYL A (UG/L)	3.7 - 6.5	4.8	4.2	15.8 - 20.7	18.0	17.6	8.4 - 13.3	10.8	10.7
SECCHI (METERS)	0.9 - 1.8	1.4	1.4	****** - **********			1.0 - 1.8	1.4	1.5

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
05/04/73	1. Flagellates	975
	2. Melosira sp.	326
	3. Coccoid cells	274
	4. Asterionella sp.	222
	5. Aphanizomenon sp.	171
	Other genera	616
	Total	2,584
08/04/73	1. Aphanizomenon sp.	4,459
	2. Lyngbya sp.	4,144
	3. Achnanthes sp.	3,108
	4. Synedra sp.	1,982
	5. Dactylococcopsis sp.	766
	Other genera	2,251
	Total	16,710
10/13/73	1. Oscillatoria sp.	3,942
	2. Achnanthes sp.	1,099
	3. Coccoid cells	1,084
	4. Dactylococcopsis sp.	848
	5. Lyngbya sp.	597
	Other genera	1,051
	Total	8,621

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
05/04/73	1	4.2
	2	3.7
	3	6.5
08/04/73	1	17.6
	2	15.8
	3	20.7
10/13/73	1	8.4
	2	10.7
	3	13.3

C. Limiting Nutrient Study:

1. Filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.020	1.620	2.3
0.050 P	0.070	1.620	18.5
0.050 P + 1.0 N	0.070	2.620	21.5
1.0 N	0.020	2.620	2.6

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Winona Lake was moderately high at the time the sample was collected (05/04/73). Also, an eight-fold increase in yield with the addition of orthophosphorus indicates phosphorus limitation at that time. Note that the addition of only nitrogen resulted in a yield not significantly greater than that of the control.

The lake data indicate phosphorus limitation in August as well (the mean inorganic nitrogen/orthophosphorus ratio was 112/1) but nitrogen limitation in October (the mean N/P ratio was 8/1).

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Indiana National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of February and March when two samples were collected. Sampling was begun in June, 1973, and was completed in May, 1974.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Indiana District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads at stations B-1 and C-1, in $kg/km^2/year$, and multiplying the means by the ZZ area in km^2.

The estimated phosphorus load from septic tanks was reduced by 50% to adjust for a phosphate detergent ban which has been in effect in Indiana since January, 1972.

A. Waste Sources:

1. Known municipal - None

* See Working Paper No. 175.

2. Known industrial -

Name	Kind of Waste	Receiving Water
Litchfield Creamery	milk	storm sewer to Winona Lake
Indiana Briquetting Co.	oil	storm sewer to Winona Lake
Gatke Corp.	oil	storm sewer to Winona Lake
Dalton Foundry	oil	storm sewer to Winona Lake

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Peterson Ditch	655	36.3
Keefer-Evans Ditch	180	10.0
Wyland Ditch	845	46.8
b. Minor tributaries & immediate drainage (non-point load) -	70	3.9
c. Known municipal STP's - None	-	-
d. Septic tanks* -	15	0.8
e. Industrial - Unknown	?	-
f. Direct precipitation** -	40	2.2
Total	1,805	100.0

2. Outputs -

Lake outlet - Eagle Creek 945

3. Net annual P accumulation - 860 kg.

* Estimate based on 120 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Peterson Ditch	27,480	30.5
Keefer-Evans Ditch	10,800	12.0
Wyland Ditch	44,740	49.5
b. Minor tributaries & immediate drainage (non-point load) -	3,495	3.9
c. Known municipal STP's - None	-	-
d. Septic tanks* -	1,280	1.4
e. Industrial - Unknown	?	-
f. Direct precipitation** -	2,450	2.7
Total	90,245	100.0

2. Outputs -

Lake outlet - Eagle Creek	69,525

3. Net annual N accumulation - 20,720 kg.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Peterson Ditch	22	916
Keefer-Evans Ditch	16	973
Wyland Ditch	23	1,243

* Estimate based on 120 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.80	0.38	39.8	9.1

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Winona Lake:	
"Dangerous" (eutrophic loading)	0.62
"Permissible" (oligotrophic loading)	0.31

V. LITERATURE REVIEWED

BonHomme, Harold L., 1976. Personal communication (review of preliminary report). IN Div. of Water Poll. Contr., Indianapolis.

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VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
1805	CATAWACT LAKE	0.058	1.660	466.667	10.744	15.000	0.013
1811	GEIST RESERVOIR	0.074	1.080	472.500	45.950	11.600	0.009
1817	JAMES LAKE	0.024	1.030	434.000	11.533	15.000	0.004
1827	MISSISSINEWA RESERVOIR	0.107	2.400	473.444	15.778	15.000	0.029
1828	MONROE RESERVOIR	0.025	0.325	438.823	6.947	15.000	0.007
1829	MORSE RESERVOIR	0.084	3.325	473.222	56.167	15.000	0.009
1836	WAWASEE LAKE	0.012	0.210	364.500	5.000	14.600	0.003
1837	WEBSTER LAKE	0.025	0.790	431.000	11.500	15.000	0.005
1839	WHITEWATER LAKE	0.084	1.620	470.167	33.083	15.000	0.012
1840	WINONA LAKE	0.035	1.250	444.667	11.211	15.000	0.011
1841	WESTLER LAKE	0.035	0.860	427.125	10.712	15.000	0.013
1842	WITMER LAKE	0.035	0.900	440.333	11.917	15.000	0.011
1843	LAKE MAXINKUCKEE	0.020	0.220	400.400	5.483	15.000	0.003
1844	TIPPECANOE LAKE	0.019	0.195	391.500	6.050	15.000	0.005
1845	DALLAS LAKE	0.029	0.830	413.333	10.067	15.000	0.014
1846	OLIN LAKE	0.012	1.460	403.333	4.867	14.900	0.003
1847	OLIVER LAKE	0.009	0.920	392.000	3.767	14.800	0.004
1848	SYLVAN LAKE	0.170	0.130	469.833	47.480	14.800	0.017
1849	HOVEY LAKE	0.062	1.050	489.333	84.267	7.600	0.024
1850	VERSAILLES LAKE	0.139	1.090	482.000	25.078	14.500	0.019
1851	BASS LAKE	0.040	0.250	471.375	29.367	7.000	0.012
1852	CROOKED LAKE	0.019	0.120	410.111	5.578	15.000	0.005
1853	LAKE JAMES	0.016	0.190	352.444	4.856	15.000	0.005
1854	LONG LAKE	0.204	1.920	442.667	16.100	15.000	0.150
1855	PIGEON LAKE	0.058	1.945	442.667	11.900	15.000	0.015
1856	MARSH LAKE	0.093	0.270	451.333	34.467	15.000	0.055
1857	HAMILTON LAKE	0.033	0.720	413.167	17.450	15.000	0.018

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	SDD-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
1805	CATARACT LAKE	37 (9)	15 (4)	31 (8)	62 (16)	35 (0)	37 (9)	217
1811	GEIST RESERVOIR	27 (7)	35 (9)	15 (4)	12 (3)	92 (24)	62 (16)	243
1817	JAMES LAKE	73 (19)	42 (11)	58 (15)	50 (13)	35 (0)	65 (17)	323
1827	MISSISSINEWA RESERVOIR	12 (3)	4 (1)	8 (2)	38 (10)	35 (0)	8 (2)	105
1828	MONROE RESERVOIR	67 (17)	69 (18)	54 (14)	73 (19)	35 (0)	69 (18)	367
1829	MONSE RESERVOIR	23 (6)	0 (0)	12 (3)	4 (1)	35 (0)	58 (15)	132
1836	WAWASEE LAKE	94 (24)	85 (22)	96 (25)	88 (23)	85 (22)	98 (25)	546
1837	WEBSTER LAKE	67 (17)	62 (16)	62 (16)	54 (14)	35 (0)	81 (21)	361
1839	WHITEWATER LAKE	19 (5)	19 (5)	23 (6)	19 (5)	35 (0)	42 (11)	157
1840	WINONA LAKE	50 (12)	27 (7)	38 (10)	58 (15)	35 (0)	52 (13)	260
1841	WESTLER LAKE	50 (12)	54 (14)	65 (17)	65 (17)	35 (0)	37 (9)	306
1842	WITMER LAKE	50 (12)	50 (13)	50 (13)	42 (11)	35 (0)	52 (13)	279
1843	LAKE MAXINKUCKEE	77 (20)	81 (21)	85 (22)	85 (22)	35 (0)	98 (25)	461
1844	TIPPECANOE LAKE	85 (22)	88 (23)	92 (24)	77 (20)	35 (0)	85 (22)	462
1845	DALLAS LAKE	62 (16)	58 (15)	69 (18)	69 (18)	35 (0)	31 (8)	324
1846	OLIN LAKE	94 (24)	23 (6)	81 (21)	92 (24)	73 (19)	92 (24)	455
1847	OLIVER LAKE	100 (26)	46 (12)	88 (23)	100 (26)	79 (20)	88 (23)	501
1848	SYLVAN LAKE	4 (1)	96 (25)	27 (7)	8 (2)	79 (20)	23 (6)	237
1849	HOVEY LAKE	31 (8)	38 (10)	0 (0)	0 (0)	96 (25)	12 (3)	177
1850	VERSAILLES LAKE	8 (2)	31 (8)	4 (1)	27 (7)	88 (23)	15 (4)	173
1851	BASS LAKE	42 (11)	77 (20)	19 (5)	23 (6)	100 (26)	46 (12)	307
1852	CROOKED LAKE	81 (21)	100 (26)	77 (20)	81 (21)	35 (0)	75 (19)	449
1853	LAKE JAMES	88 (23)	92 (24)	100 (26)	96 (25)	35 (0)	75 (19)	486
1854	LONG LAKE	0 (0)	12 (3)	44 (11)	35 (9)	35 (0)	0 (0)	126
1855	PIGEON LAKE	37 (9)	8 (2)	44 (11)	46 (12)	35 (0)	27 (7)	197
1856	MARSH LAKE	15 (4)	73 (19)	35 (9)	15 (4)	35 (0)	4 (1)	177
1857	HAMILTON LAKE	58 (15)	65 (17)	73 (19)	31 (8)	35 (0)	19 (5)	281

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	1836	WAWASEE LAKE	546
2	1847	OLIVER LAKE	501
3	1853	LAKE JAMES	486
4	1844	TIPPECANOE LAKE	462
5	1843	LAKE MAXINKUCKEE	461
6	1846	OLIN LAKE	455
7	1852	CROOKED LAKE	449
8	1828	MONROE RESERVOIR	367
9	1837	WEBSTER LAKE	361
10	1845	DALLAS LAKE	324
11	1817	JAMES LAKE	323
12	1851	BASS LAKE	307
13	1841	WESTLER LAKE	306
14	1857	HAMILTON LAKE	281
15	1842	WITMER LAKE	279
16	1840	WINONA LAKE	260
17	1811	GEIST RESERVOIR	243
18	1848	SYLVAN LAKE	237
19	1805	CATARACT LAKE	217
20	1855	PIGEON LAKE	197
21	1856	MARSH LAKE	177
22	1849	HOVEY LAKE	177
23	1850	VERSAILLES LAKE	173
24	1839	WHITEWATER LAKE	157
25	1829	MORSE RESERVOIR	132
26	1854	LONG LAKE	126
27	1827	MISSISSINEWA RESERVOIR	105

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR INDIANA 03/29/76

LAKE CODE 1840 WINONA LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 83.1

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1840A1	83.1	1.02	1.20	1.69	1.58	1.03	0.78	0.47	0.17	0.16	0.17	0.41	0.74	0.78
1840B1	30.0	0.354	0.430	0.617	0.575	0.368	0.283	0.170	0.054	0.054	0.057	0.147	0.275	0.281
1840C1	11.1	0.127	0.159	0.232	0.212	0.136	0.105	0.062	0.018	0.019	0.019	0.054	0.105	0.104
1840D1	36.8	0.428	0.515	0.736	0.688	0.442	0.337	0.204	0.068	0.065	0.068	0.176	0.311	0.335
1840ZZ	3.6	0.040	0.051	0.076	0.071	0.042	0.034	0.020	0.005	0.006	0.006	0.018	0.034	0.033

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 83.1
SUM OF SUB-DRAINAGE AREAS = 80.8
TOTAL FLOW IN = 9.07
TOTAL FLOW OUT = 9.43

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
1840A1	6	73	1.246	9	2.718				
	7	73	0.266	14	0.198				
	8	73	0.110	11	0.142				
	9	73	0.088	15	0.076				
	10	73	0.153	13	0.144				
	11	73	0.241	11	0.125				
	12	73	1.076	5	0.651				
	1	74	1.982	19	1.246				
	2	74	1.472	2	1.982	15	0.850		
	3	74	2.039	2	1.274	16	1.841		
	4	74	1.303	13	1.416				
	5	74	1.189	19	1.812				
1840B1	6	73	0.453	9	0.595				
	7	73	0.096	14	0.074				
	8	73	0.040	11	0.051				
	9	73	0.031	15	0.028				
	10	73	0.057	13	0.054				
	11	73	0.091	11	0.045				
	12	73	0.396	5	0.244				
	1	74	0.736	19	0.453				
	2	74	0.538	2	0.736	15	0.340		
	3	74	0.736	2	0.481	16	0.680		
	4	74	0.481	13	0.538				
	5	74	0.425	19	0.651				

TRIBUTARY FLOW INFORMATION FOR INDIANA 03/29/76

LAKE CODE 1840 WINONA LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
1840C1	6	73	0.164	9	0.396				
	7	73	0.034	14	0.025				
	8	73	0.014	11	0.017				
	9	73	0.011	15	0.011				
	10	73	0.020	13	0.020				
	11	73	0.031	11	0.017				
	12	73	0.142	15	0.0				
	1	74	0.266	19	0.164				
	2	74	0.193	2	0.258	15	0.113		
	3	74	0.263	2	0.170	16	0.249		
	4	74	0.176	13	0.193				
	5	74	0.159	19	0.238				
1840D1	6	73	0.538	9	1.218				
	7	73	0.116	14	0.088				
	8	73	0.048	11	0.059				
	9	73	0.037	15	0.031				
	10	73	0.065	13	0.062				
	11	73	0.102	11	0.054				
	12	73	0.453	5	0.283				
	1	74	0.878	19	0.538				
	2	74	0.623	2	0.850	15	0.368		
	3	74	0.850	2	0.538	16	0.850		
	4	74	0.566	13	0.623				
	5	74	0.510	19	0.765				
1840ZZ	6	73	0.054	9	0.127				
	7	73	0.011	14	0.008				
	8	73	0.005	11	0.005				
	9	73	0.004	15	0.004				
	10	73	0.007	13	0.006				
	11	73	0.010	11	0.005				
	12	73	0.045	5	0.028	15	0.0		
	1	74	0.088	19	0.054				
	2	74	0.062	2	0.085	15	0.037		
	3	74	0.085	2	0.057	16	0.082		
	4	74	0.057	13	0.062				
	5	74	0.051	19	0.0				

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/03/30

184001
41 13 03.0 085 49 39.0 3
WINONA LAKE
18085 INDIANA

051791

11EPALES 2111202
0070 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/04	14 35	0000	12.8		54	500	8.30	203	0.110	0.800	1.440	0.009
	14 35	0006	12.8	9.7		520	8.30	203	0.100	0.600	1.480	0.009
	14 35	0015	12.8	9.4		500	8.30	202	0.100	0.800	1.360	0.011
	14 35	0022	12.8	9.5		500	8.30	203	0.100	0.700	1.340	0.016
	14 35	0035	12.7	9.0		520	8.40	203	0.100	0.700	1.390	0.011
	14 35	0045	10.8	9.1		490	8.20	202	0.110	0.700	1.470	0.014
	14 35	0055	9.2	7.9		500	8.20	182	0.240	0.900	1.390	0.038
	14 35	0066	9.1	6.4		500	8.20	166	0.320	0.900	1.200	0.056
73/08/04	09 25	0000	23.6			461	8.60	182	0.060	1.200	0.410	0.006
	09 25	0005	23.1	7.6		460	8.40	183	0.050	1.000	0.450	0.011
	09 25	0015	22.8	6.0		461	8.20	185	0.090	1.000	0.580	0.006
73/10/13	13 15	0000	19.9		70	415	8.40	176	0.070	1.300	0.050	0.018
	13 15	0005	19.8	8.0		410	8.40	170	0.050	0.900	0.050	0.014
	13 15	0015	19.7	6.4		411	8.20	171	0.060	0.600	0.060	0.018
	13 15	0025	17.3	0.4		408	7.70	185	0.280	1.500	0.130	0.028
	13 15	0035	12.2	0.2		385	7.60	186	0.700	1.800	0.380	0.097
	13 15	0050	10.9	0.0		377	7.50	215	1.600	2.700	0.040	0.227
	13 15	0068	10.3	0.0		378	7.40	225	2.420	3.800	0.060	0.376

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/04	14 35	0000	0.027	4.2
	14 35	0006	0.038	
	14 35	0015	0.040	
	14 35	0022	0.033	
	14 35	0035	0.037	
	14 35	0045	0.037	
	14 35	0055	0.062	
	14 35	0066	0.088	
73/08/04	09 25	0000	0.022	17.6
	09 25	0005	0.023	
	09 25	0015	0.023	
73/10/13	13 15	0000	0.029	8.4
	13 15	0005	0.029	
	13 15	0015	0.036	
	13 15	0025	0.056	
	13 15	0035	0.124	
	13 15	0050	0.305	
	13 15	0068	0.438	

STORET RETRIEVAL DATE 76/03/30

184002
41 13 43.0 085 50 00.0 3
WINONA LAKE
18085 INDIANA
051791

11EPALES 2111202
0060 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/04	15 00	0000	12.6		72	540	8.30	203	0.110	0.800	1.420	0.010
	15 00	0005	12.6	9.4		520	8.30	203	0.100	0.700	1.570	0.010
	15 00	0015	12.6	8.5		500	8.30	203	0.110	0.700	1.390	0.011
	15 00	0025	12.6	8.8		500	8.20	203	0.120	0.800	1.480	0.013
	15 00	0040	10.6	8.6		500	8.20	203	0.170	0.900	1.390	0.021
	15 00	0056	9.5	8.6		470	8.20	203	0.180	0.600	1.410	0.026
73/08/03	10 00	0000	23.5			461	8.50	183	0.060	1.100	0.440	0.005
	10 00	0005	22.7	8.1		461	8.40	184	0.060	0.700	0.450	0.004
	10 00	0015	22.9	6.5		462	8.20	184	0.090	0.700	0.470	0.003
	10 00	0025	14.0	0.0		411	7.50	212	0.180	0.800	1.230	0.003
73/10/13	12 40	0000	20.0		60	412	8.50	165	0.080	1.100	0.040	0.008
	12 40	0005	20.0	8.4		412	8.50	165	0.040	1.000	0.030	0.008
	12 40	0015	20.0	8.2		409	8.40	163	0.060	1.000	0.040	0.015
	12 40	0025	18.6	2.0		410	7.80	176	0.170	1.000	0.130	0.021
	12 40	0040	11.7	0.0		383	7.50	194	0.990	2.100	0.260	0.138
	12 40	0051	10.5	0.0		380	7.50	225	2.080	3.300	0.040	0.336

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/ P	32217 CHLRPHYL A UG/L
73/05/04	15 00	0000	0.028	3.7
	15 00	0006	0.029	
	15 00	0015	0.032	
	15 00	0025	0.032	
	15 00	0040	0.041	
	15 00	0056	0.045	
73/08/03	10 00	0000	0.020	15.8
	10 00	0005	0.022	
	10 00	0015	0.022	
	10 00	0025	0.020	
73/10/13	12 40	0000	0.026	10.7
	12 40	0005	0.031	
	12 40	0015	0.029	
	12 40	0025	0.035	
	12 40	0040	0.164	
	12 40	0051	0.378	

25

STORET RETRIEVAL DATE 76/03/30

184003
41 13 36.0 085 50 38.0 3
WINONA LAKE
18085 INDIANA
051791

11EPALES 2111202
0016 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/04	15 30	0000	13.4		36	520	8.40	182	0.080	0.900	1.320	0.004
	15 30	0005	13.2	9.6		500	8.40	203	0.070	0.800	1.340	0.005
	15 30	0012	13.2	9.8		540	8.40	180	0.090	0.700	1.320	0.005
73/08/04	10 20	0000	23.7			446	8.60	176	0.060	0.800	0.250	0.005
	10 20	0005	23.4	8.5		444	8.40	177	0.070	0.900	0.230	0.005
	10 20	0011	22.8	5.0		450	8.10	180	0.190	0.900	0.240	0.005
73/10/13	12 25	0000	20.0		40	404	8.50	160	0.050	1.300	0.040	0.014
	12 25	0005	20.0	7.8		404	8.40	160	0.040	1.200	0.040	0.010
	12 25	0010	20.0	6.0		408	8.20	160	0.120	1.200	0.040	0.007

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/04	15 30	0000	0.038	6.5
	15 30	0005	0.051	
	15 30	0012	0.037	
73/08/04	10 20	0000	0.032	20.7
	10 20	0005	0.032	
	10 20	0011	0.033	
73/10/13	12 25	0000	0.042	13.3
	12 25	0005	0.040	
	12 25	0010	0.045	

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/03/30

1840A1
41 13 30.0 085 50 46.0 4
EAGLE CREEK
18 7.5 WARSAW
0/WINONA LAKE 051791
BRDG ON PAKERTON RD WNW OF WRSW RADIO TW
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	14 45		1.040	0.610	0.024	0.006	0.030
73/07/14	09 15		0.270	2.700	0.080	0.006	0.025
73/08/11	08 50		0.012	2.500	0.100	0.005	0.035
73/09/15	08 15		0.031	2.500	0.088	0.008	0.035
73/10/13	09 00		1.400	0.850	0.030	0.016	0.050
73/11/11	10 05		0.115	0.850	0.115	0.012	0.045
73/12/05	09 26		0.336	1.100	0.124	0.012	0.030
74/01/19	14 00		1.090	0.800	0.048	0.020	0.035
74/02/02	10 20		1.760	0.800	0.030	0.025	0.050
74/02/15	12 30		1.760	1.400	0.060	0.015	0.045
74/03/02	10 00		1.760	1.400	0.070	0.025	0.055
74/03/16	09 00		1.850	1.800	0.050	0.015	0.045
74/04/13	08 40		1.700	2.300	0.055	0.010	0.010
74/05/19	12 40		1.400	1.400	0.080	0.010	0.040

STORET RETRIEVAL DATE 76/03/30

184081
41 12 45.0 085 49 45.0 4
PETERSON DITCH
18 7.5 WARSAW
I/WINONA LAKE 051791
BASS RD BRDG AT S END OF LAKE
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	15 00		1.920	2.000	0.110	0.042	0.105
73/07/14	09 25		0.500	2.000	0.075	0.009	0.020
73/08/11	09 00		0.420	1.600	0.370	0.009	0.030
73/09/15	08 20		0.399	1.200	0.072	0.054	0.100
73/10/13	09 10		0.590	1.200	0.084	0.016	0.080
73/11/11	10 15		0.294	0.450	0.016	0.008	0.025
73/12/05	09 40		1.260	0.900	0.076	0.012	
74/01/19	14 10		3.500	1.500	0.086	0.028	0.240
74/02/02	10 25		3.100	0.800	0.050	0.025	0.075
74/02/15	12 35		1.680	1.500	0.095	0.015	0.060
74/03/02	10 05		2.080	1.000	0.015	0.015	0.045
74/03/16	09 05		1.760	1.700	0.045	0.015	
74/04/13	08 45		1.180	1.500	0.025	0.015	0.035
74/05/19	12 45		1.500	1.400	0.070	0.020	0.060

STORET RETRIEVAL DATE 76/03/30

1840C1
41 12 54.0 085 49 13.0 4
KEEFER-EVANS DITCH
18 7.5 WARSAW
T/WINONA LAKE 051791
WOOD FOOT BRDG AT CHI. BOYSCLUB CAMP
11EPALES 2111204
0000 FEET DEPTH CLASS 00

	DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
	73/06/09	15	25	1.240	1.980	0.160	0.031	0.125
	73/07/14	09	35	0.620	0.900	0.035	0.012	0.045
	73/08/11	09	10	0.660	2.500	0.540	0.015	0.055
W	73/09/15	08	35	0.650	1.570	0.132	0.019	0.070
Q	73/10/13	09	20	0.570	0.950	0.086	0.015	0.065
	73/11/11	10	25	0.690	0.475	0.044	0.008	0.035
	74/01/19	14	40	3.960	1.400	0.104	0.016	0.085
	74/02/02	10	00	3.000	0.850	0.060	0.010	0.030
	74/02/15	12	40	2.200	1.200	0.065	0.010	0.060
	74/03/02	10	15	2.200	1.300	0.035	0.010	0.030
	74/03/16	09	10	2.000	1.650	0.050	0.015	0.052
	74/04/13	08	50	1.520	1.600	0.060	0.010	0.010
	74/05/19	13	00	1.180	1.200	0.075	0.015	0.045

STORET RETRIEVAL DATE 76/03/30

184001
41 13 15.0 085 49 15.0 4
WYLAND DITCH
18 7.5 WARSAW
I/WINONA LAKE 051791
PARK AVE BRDG S END COM OF WINONA LAKE
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	15 35		1.600	2.730	0.072	0.043	0.165
73/07/14	09 46		2.040	0.750	0.017	0.020	0.045
73/08/11	09 20		1.600	1.470	0.071	0.025	0.075
73/09/15	08 45		2.060	0.690	0.024	0.019	0.050
73/10/13	09 30		1.400	0.880	0.035	0.017	0.045
73/11/11	10 30		1.740	0.600	0.016	0.005K	0.025
73/12/05	09 35		1.840	1.400	0.132	0.016	0.055
74/01/19	13 45		3.520	2.300	0.160	0.036	0.160
74/02/02	09 45		4.200	1.200	0.085	0.032	0.115
74/02/15	12 20		3.080	1.400	0.115	0.015	0.070
74/03/02	09 45		3.100	1.200	0.070	0.025	0.085
74/03/16	08 50		2.700	1.900	0.090	0.030	0.105
74/04/13	08 30		2.100	2.100	0.045	0.015	0.015
74/05/19	12 20		1.760	1.850	0.070	0.010	0.095

K VALUE KNOWN TO BE
LESS THAN INDICATED